Relativity

Galileo - 1500s

- Copernican model of solar system - evidence was the moons of Jupiter.
- Why don't you feel the Earth going around the sun? Inertia - objects in motion stay in motion.
- relativity - all motion is relative to your frame of reference(arbitrary coordinate system). You can't tell if you are moving.

Galilean addition of velocities:

eg. You are on a train going North at 20.0 m/s. You walk on the train at 2.0 m/s. What is your velocity if

a) you are walking North on the train - frame of reference ground.
b) you are walking South on the train- frame of reference ground.
c) What is the velocity of the ground in the frame of reference of the train?

a) 22.0m/s North
b) 18.0m/s North
c) 20.0 m/s South

video: https://www.youtube.com/watch?v=Ip_jdcA8fcw&index=41&list=PL8

_xPU5epJddRABXqJ5h5G0dk-XGtA5cZ
playback at 1.5X

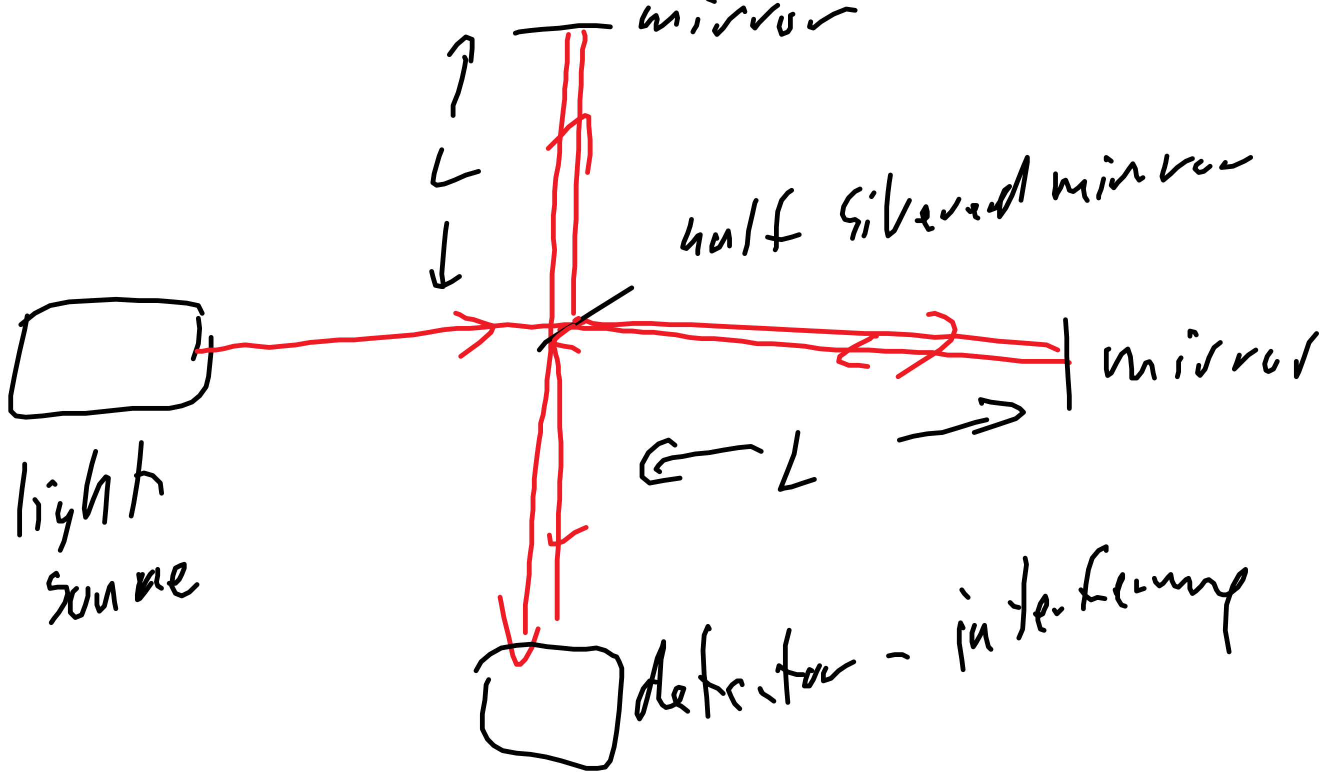
Watch 41-44

42 is the key episode - watch with taking your own notes:

Michelson Morley experiment:

1800s scientists believed that the vacuum was filled with Ether - light is a wave, what is waving?, Ether. Æther

so, light should move at a different speed depending on Earth's motion through the Æther.



there is no interference between the beams,

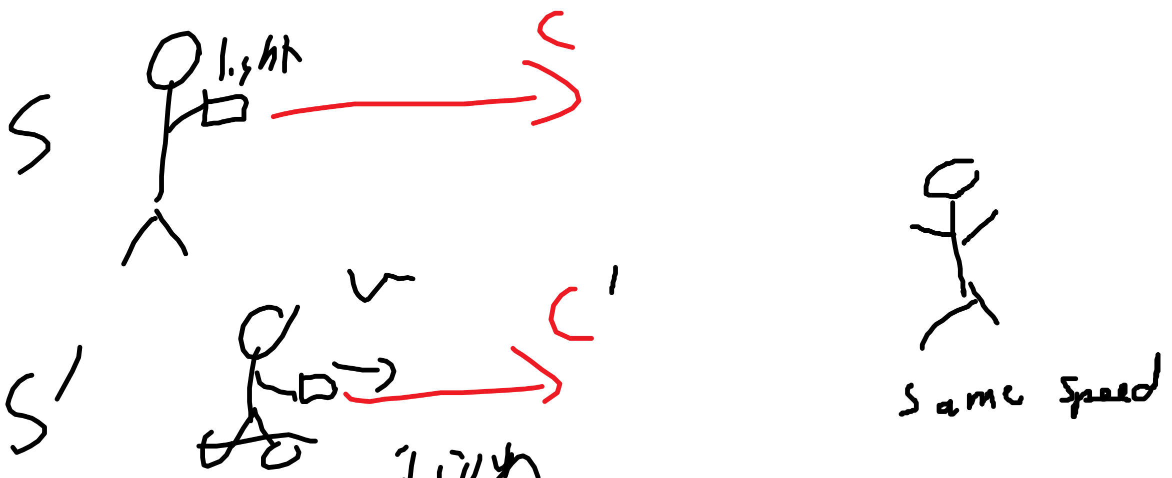
regardless of the orientation relative to the motion of the Earth.

Conclusion - there is no Æther, only vacuum.

Separately, Einstein looked at Electromagnetic theory and observed c comes out of the equations independent of the frame of reference.

How can velocity be independent of frame?

eg.



Galileo

position

$$x' = x - vt$$

$$u' = u - v$$

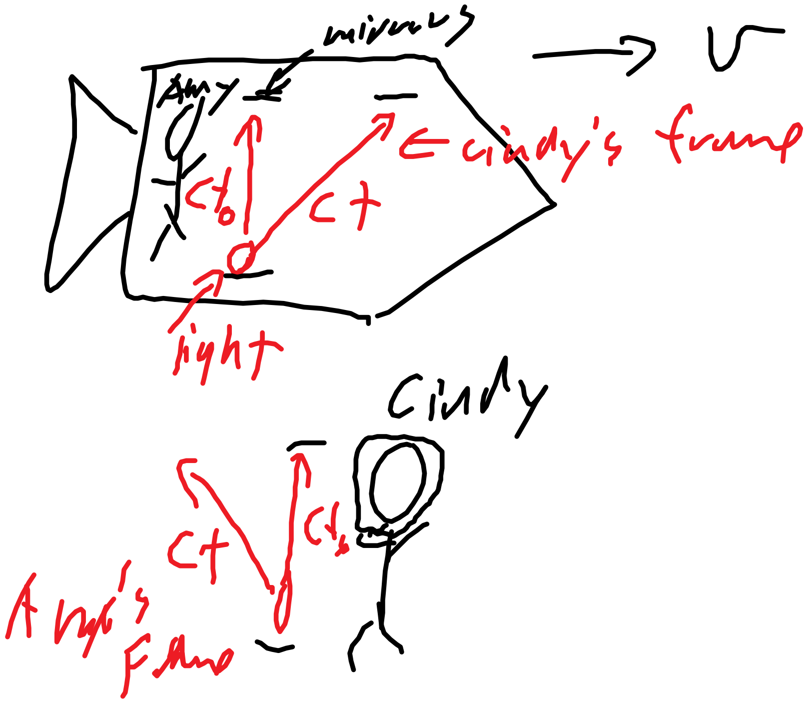
Velocity in frame S' — velocity in frame S — relative velocity of S to S'

go back to the walking on train example

u = 2.0m/s v = -20m/s u'= 22m/s
but if we use light, it doesn't work
c' = c regardless of v. What? Weird!

Thought experiments

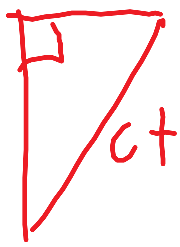
1. Light clock in two frames of reference.



if we accept the postulate (assumption) that the speed of light is the same in all frames of reference, then
the time in Amy's frame is t_o when measured by Amy (proper time) and t when measure in Cindy's frame (relativistic time).
t is slower than t_o
but the same thing happens when we look at Cindy's time.

How can both time be slower?

Let's do some math:



solve for t

$$a^2 + b^2 = c^2$$

$$(vt)^2 + (ct_0)^2 = (ct)^2$$

$$v^2t^2 + c^2t_0^2 = c^2t^2$$

$$c^2t_0^2 = (c^2 - v^2)t^2$$

$$t_0^2 = \left(1 - \frac{v^2}{c^2}\right)t^2$$

$$t_0 = \sqrt{1 - \frac{v^2}{c^2}}\; t$$

$$t = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\, t_0$$

$$\gamma = \frac{1}{\sqrt{\ \ldots\ }}$$

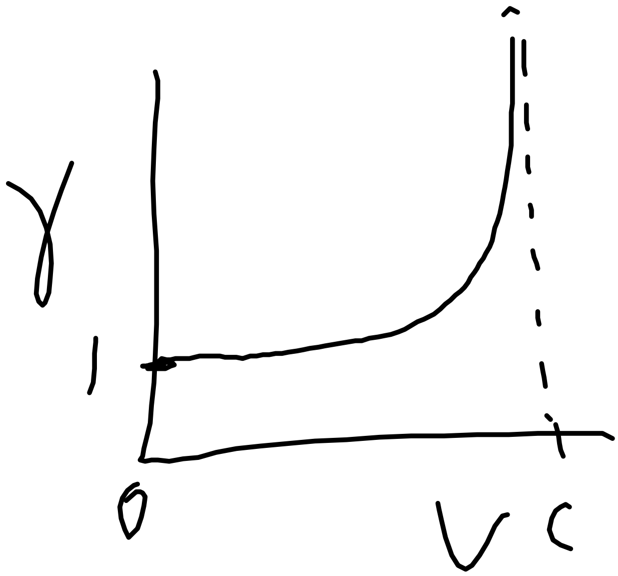
$v \to 0$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$v \to 0$
$\gamma \to 1$

$v \to c$
$\gamma \to \infty$

asymptote $v \to c$



V never gets to c

We still haven't solved the paradox.
How can both clocks go slower?

Answer: time is dependent on velocity and position.
simultaneity - things happen at the same time, depends on relative velocity and position.

Lorentz transformations:
how space and time are altered when you shift frames of reference.

distances in the direction of motion

$L=L_o/\gamma$

are contracted by a factor of gamma.

more generally:

$x' = \gamma(x-vt)$ (like $x'=x-vt$ for Galileo)
but
$t'=\gamma\{t-[(vx)/c^2]\}$ (Galileo $t'=t$)

eg. Cosmic ray muons are produced in the upper atmosphere, 80 km up, and move at 0.99c to Earth. They have a lifetime of 2.2×10^{-6}s.

a) what is the lifetime of muons in the frame of reference of the Earth?
b) what is the height of the atmosphere in the frame of reference of the muons?
c) how long does it take for the muons to reach the Earth in i) Earth's frame ii)muon's frame

Cambridge study guide is free:

p26 Q10,11,16,18